Texas Watershed Planning Short Course

Prioritizing and Selecting Management Strategies
(“What do we do next?”)

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Two Major Aspects of Integrated Water Resources Management

- ***Scientific, technical & engineering*** *concerns (e.g., geology, flora, fauna, physiography, water supply-demand equation, population centers, pollution sources, topography)*

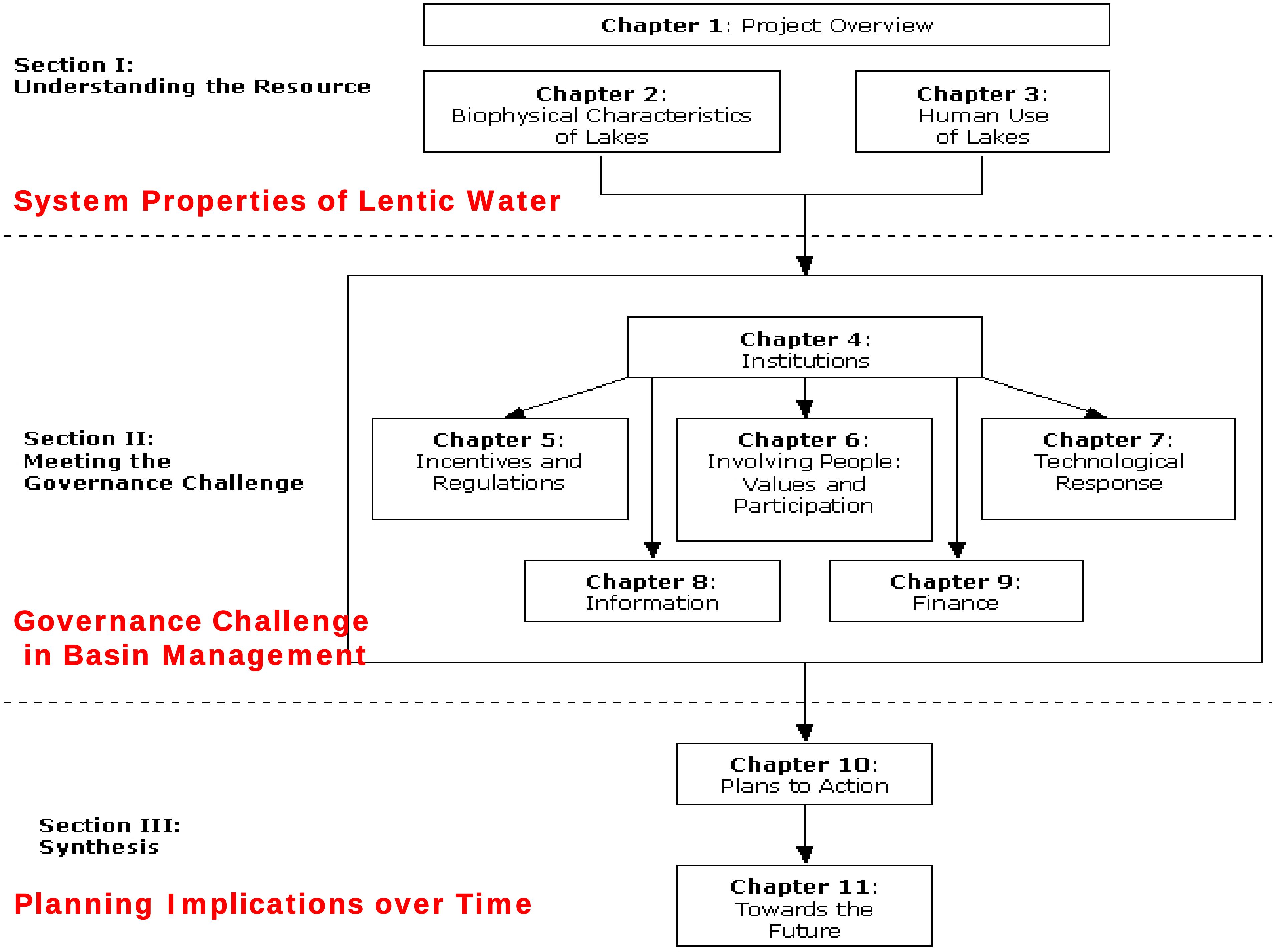
  *→ Fundamentally define the "**state**" of the water resource (how much, what condition, where is it located, relative availability, etc.)*

Two Major Aspects of Integrated Water Resources Management

- ***Socio-economic concerns***

  (e.g., institutions, policies, financing, public awareness, stakeholder participation, political realities, cultural values)

  *→ Fundamentally define **HOW** humans use their water resources*


Chapter 1: Project Overview
Section I:
Understanding the Resource
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Planning Implications over Time

Steps to Selecting Management Practices

(1) *Inventory* ***existing management efforts*** *in watershed;*

(2) ***Quantify effectiveness*** *of current management practices;*

(3) *Identify* ***new*** *management* ***opportunities;***

(4) ***Identify critical areas*** *in watershed where additional management efforts are needed;*

Steps to Selecting Management Practices

(5) *Identify* ***possible*** *management* ***practices;***

(6) *Identify* ***relative*** *pollutant* ***reduction efficiencies;***

(7) *Develop* ***screening criteria*** *to identify opportunities & constraints;*

(8) ***Rank alternatives*** *and* ***develop candidate*** *management opportunities.*

Inventory existing management efforts in watershed

- *Identify programs, ordinances, etc., already implemented in watershed;*
- *Existing management may already incorporate complex site-specific social & economic factors; local knowledge of regional environmental constraints (Table 10-2).*

Table 10-2. Existing Programs and Policies Identified in the Mill Creek Subwatershed Communities

Stakeholder	Existing Program or Policy	Pollutant Addressed
USDA, Natural Resources Conservation Service	Wetland restoration (Wetlands Reserve Program)	Hydrologic flow
	Controlling erosion/soil information	Sediment
	Streambank stabilization expertise	Sediment
	Riparian revegetation (Conservation Reserve Program)	
	Forested revegetation/filter strips	
	Agricultural waste management (Environmental Quality Incentives Program)	Nutrients
	Soil testing	
	Cross wind strips	Wind erosion
Washtenaw County Road Commission	Leave buffers when grading gravel roads	Sediment
	Assess and manage erosion at stream crossings	
	Follow soil erosion and sediment control practices	
Village of Chelsea	Soil erosion and sediment controls and stormwater retention requirements on new developments	Sediment
	Stormwater calculations must account for roads in new development in addition to the other development	Hydrologic flow
	Large detention on wastewater treatment plant site	
	Stormwater collectors, proprietary treatment devices	
	Oil and grease separators installed; add outlet devices to existing development	Sediment, oil and grease

Quantify effectiveness of current management practices

- *Determine effectiveness of measures (e.g., load reductions & other management objectives achieved);*

- *Required pollutant load reductions*
  *- load reductions achieved with existing measures = additional load reduction practices/measures needed to take care of "**gap**"*

Identify new management options

- *Begin identifying potential new measures to address "gap" (pollutant load reductions)*

- *Includes identifying:*

  *(1) **Critical areas** requiring additional management;*

  *(2) **Candidate** management **practices;***

  *(3) **Relative** pollutant load **reductions;***

  *(4) **Opportunities & constraints** of management options;*

Identify critical areas requiring additional management

- *Need to identify critical areas for implementing management options (e.g., immediately adjacent to water system vs. upland at pollutant sources);*
  - *GIS/hand-draft maps useful (Fig. 10-2; PLUARG).*

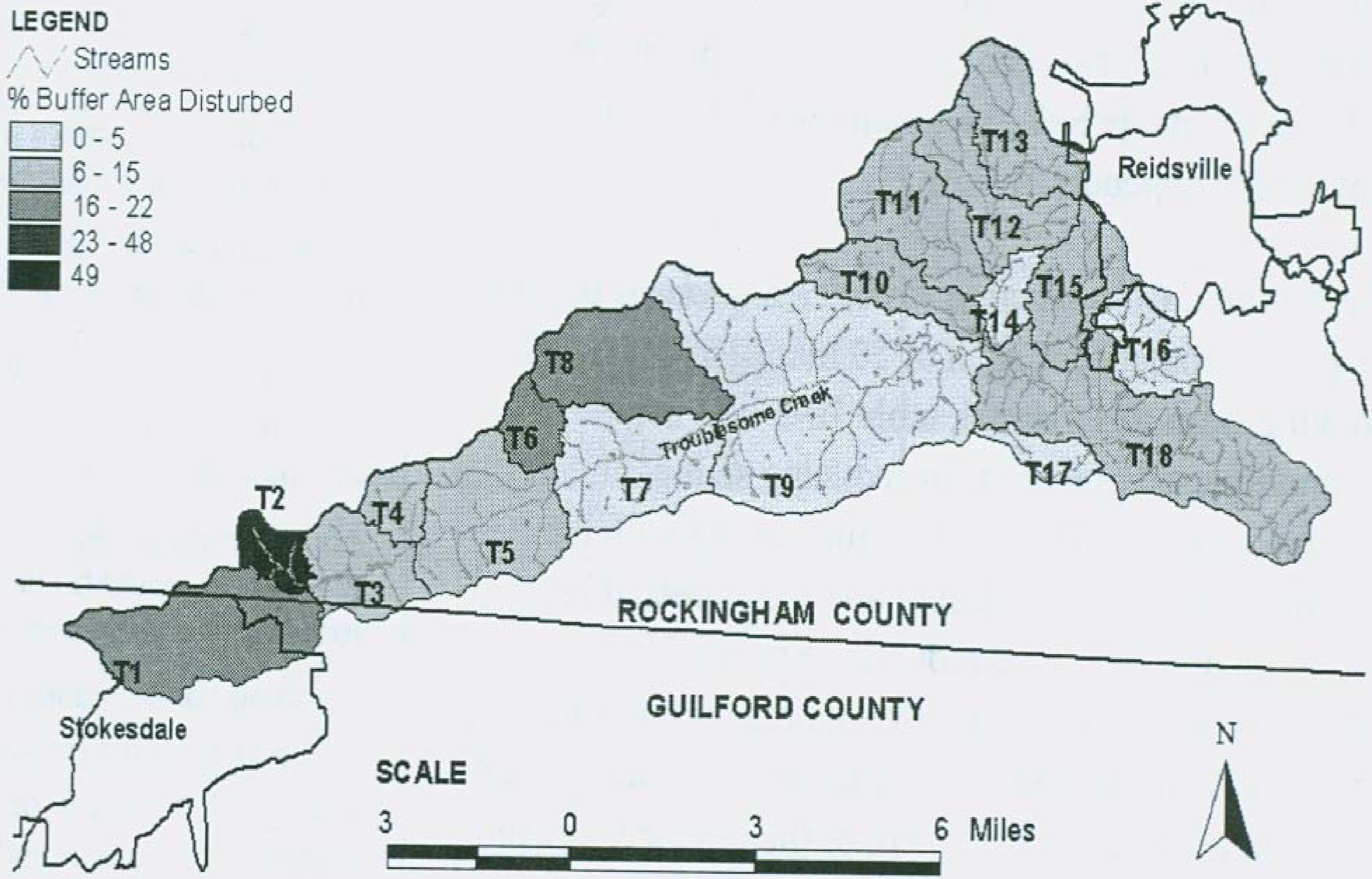


Figure 10-2. Percentage of buffer area disturbed and impaired waters in the Troublesome Creek watersheds.

PLUARG: Land Use/Land Form Characteristics

- ***Land Use*** = *Purpose for which land is being used;*
- ***Land Form*** = *Slope, soil type & texture, extent of impervious surface, drainage density, vegetative cover*

(~interposition of land relief features & soil texture maps for given basins)

(Source: Pollution From Land Use Reference Group (PLUARG; 1978))

Table 5. TOTAL PHOSPHORUS UNIT LOAD BY LAND USE AND LAND FORM (IN U.S.A.)

(KG/KM^2/YR)

FORM / USE	FINE TEXTURED 1. LEVEL	FINE TEXTURED 2. SLOPING	MEDIUM TEXTURED 3. LEVEL	MEDIUM TEXTURED 4. SLOPING	COARSE TEXTURED 5. LEVEL	COARSE TEXTURED 6. SLOPING
1. PLOWED FIELDS	106	125	87	87	23	63
2. GRASSLAND	23	23	10	10	10	10
3. DAIRY (PASTURE)	40	63	23	23	10	10
4. BRUSH	23	23	23	23	23	23
5. ORCHARD/ TRUCK CROPS	125	125	125	125	125	125
6. FOREST	10	10	10	10	10	10
7. WETLANDS	0	0	0	0	0	0
8. MISCELLANEOUS[a]	250	200	150	100	50	25

[a]VALUES DO NOT CONFORM TO LAND FORM HEADING DESCRIPTIONS. RATHER THEY ARE USED FOR SPECIAL CASES OF DOCUMENTED EVIDENCE OF EXISTING UNIT AREA LOADS IN SPECIFIC AREAS.

(taken from Johnson et al., 1978)

TABLE 10: URBAN LAND UNIT AREA LOADS

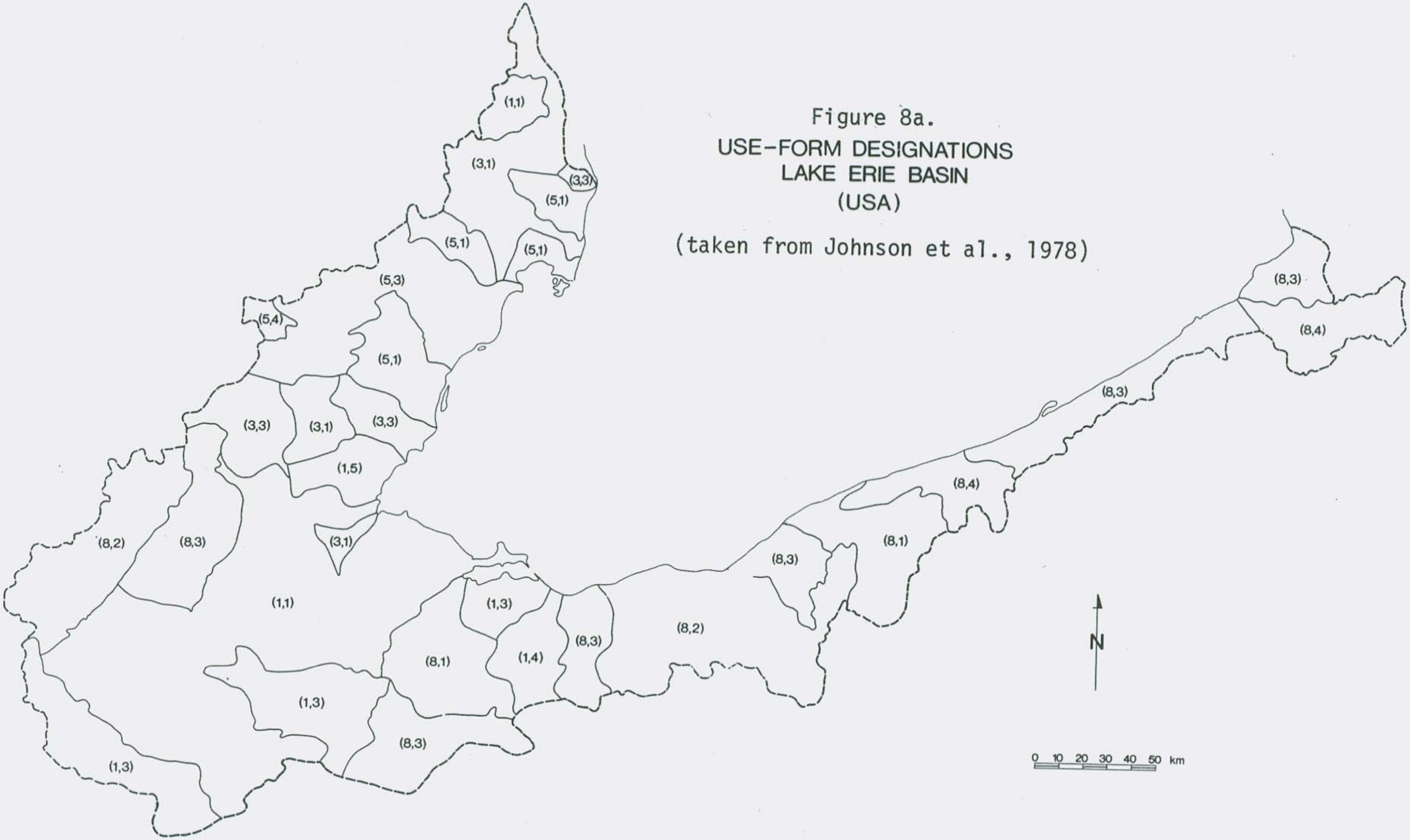
FOR TOTAL PHOSPHORUS AND SUSPENDED SOLIDS

LAND USE \ PARAMETER		TP ($KG/KM^2/YR$)	SS ($TONNES/KM^2/YR$)
AREAS OF COMBINED SEWER SYSTEMS	HI INDUSTRY	1100	72.6
	MED INDUSTRY	1000	74.3
	LOW INDUSTRY	900	75.9
AREAS OF SEPARATED SEWER SYSTEMS	HI INDUSTRY	300	66.0
	MED INDUSTRY	250	52.3
	LOW INDUSTRY	125	38.5
UNSEWERED AREAS		125	38.5
AREAS OF TOWNS 1000 - 10000 POPULATION		250	52.3

[a] FOR DEVELOPING URBAN LAND AN AGGRAVATED UNIT AREA LOAD APPLIES (FOR SUSPENDED SOLIDS $225T/KM^2/YR$ WAS USED FOR ALL LAND USES, HOWEVER FOR PHOSPHORUS A SIMPLE MULTIPLE OF THE VALUES AS THEY APPEAR ABOVE WAS EMPLOYED)

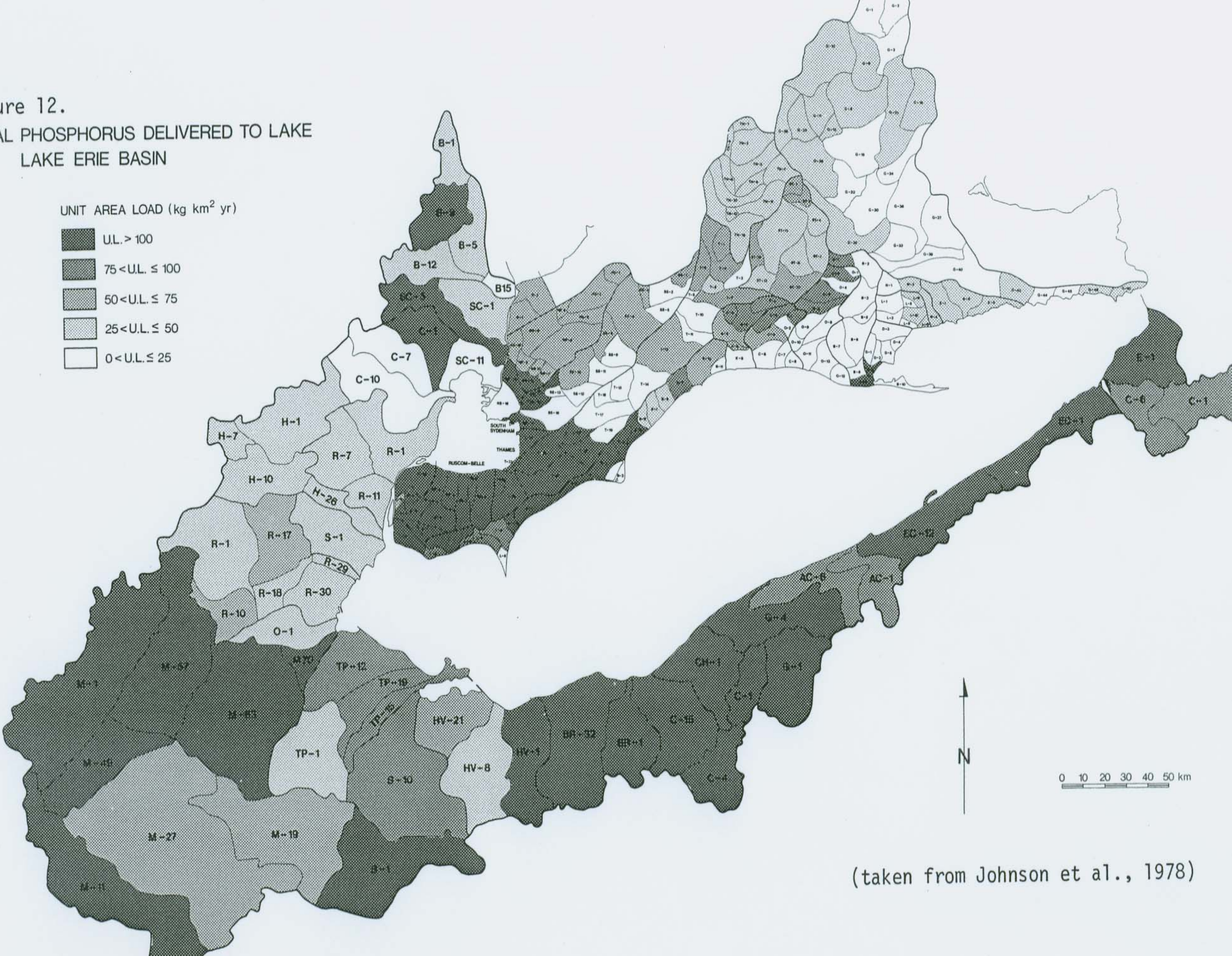
Figure 8a.
USE-FORM DESIGNATIONS
LAKE ERIE BASIN
(USA)

(taken from Johnson et al., 1978)



[a] LAND USE, LAND FORM COUPLES CORRESPOND TO CANADIAN UNIT LOAD TABLE CATEGORIES (TABLE 6) WITH THE EXCEPTION OF LAND USE CATEGORY 8 (FROM TABLE 5)

Figure 12.
TOTAL PHOSPHORUS DELIVERED TO LAKE
LAKE ERIE BASIN



(taken from Johnson et al., 1978)

Identify candidate management practices

- *Many resources for initial identification of management options;*
- *Choice depends on many factors: Pollutant sources & root causes in watershed; land use characteristics (e.g., urban vs. agriculture vs. forests).*

Identify candidate management practices

- ***Urban Sources***: *International Stormwater Best Management Practice Database (www.bmpdatabase.org)*

- ***Agricultural Sources***: *NRCS National Handbook of Conservation Practices (www.nrcs.usda.gov/Technical/Standards.nhcp.html)*

- ***All Sources*** *(agriculture, urban, forestry, marinas & recreational boating, hydromodification, wetlands): (www.epa.gov/owow/nps)*

- ***State BMP Handbooks***: *California Stormwater Best Management Practice Handbooks (www.cabmphandbooks.com)*

Table 10-3. Commonly Used Management Practices for Salinity, Sediment, and Total Dissolved Solids

Pollution Sources (✓ = Management practice applies)						Management Practice	Load Reduction (H, M, or L)
AFO	Ag Practices	Industry Runoff	Urban Runoff	Disturbed Areas	Stream Erosion		
		✓		✓		Construction site mgt	L
	✓			✓	✓	Grazing mgt	M
✓	✓					Nutrient mgt	M
	✓			✓		Cover crop	H
✓	✓			✓	✓	Fencing	H
✓	✓			✓	✓	Filter strip	H
	✓			✓		Mulching	L
	✓	✓	✓	✓	✓	Riparian buffer	M
	✓			✓	✓	Seeding	M
				✓	✓	Tree planting	L
					✓	Brush layer	H
✓	✓				✓	Brush trench	H
✓	✓			✓	✓	Erosion control fabric	H
✓	✓			✓	✓	Silt fence	M
✓				✓		Straw bale barrier	M

Identify relative pollutant reduction efficiencies

- *Can be* ***simple at screening stage*** *(H, M, L);*
- ***Many references*** *identify relative pollutant load reduction potentials (Table 10.4)*

Example: *BMP Implementation Appendix*
→Info on 85 practices (description; purpose; pollutant sources treated; pollutants addressed; potential load reduction; estimated time for load reduction);

Table 10-4. Example Management Practice Screening Matrix

Structural Management Practice	Hydrologic Factor				Pollutant Factor				
	Interception	Infiltration	Evaporation	Reduced Peak Flow	Total Suspended Solids	Nutrients	Fecal Coliform Bacteria	Metals	Temperature
Bioretention	●	◗	◗	◗	●	●	●	●	●
Conventional dry detention	○	○	◗	●	○	○	●	◗	◗
Extended dry detention	○	○	◗	●	◗	◗	●	◗	○
Grass swale	◗	◗	○	○	◗	○	○	●	◗
Green roof	●	○	●	◗	○	○	○	○	●
Infiltration trench	○	●	○	◗	●	●	●	●	●
Parking lot underground storage	◗	◗	○	●	●	●	◗	●	●
Permeable pavement	◗	◗	◗	◗	◗	○	◗	○	◗
Sand filter	○	○	○	○	●	●	◗	●	●
Stormwater wetland	●	○	◗	●	●	●	●	●	◗
Vegetated filter strip with level spreader	◗	◗	○	○	◗	◗	○	◗	◗
Water quality swale	◗	◗	◗	◗	●	●	○	●	●
Wet pond	○	○	●	●	●	●	●	●	○

○ Poor, Low, or No Influence
◗ Moderate
● Good, High

Title	Vegetative Buffer Strips	80

Keywords Forestry, Agriculture, Urban, Liquid Waste Disposal, Sediments, Nutrients

Applicable Land Use	Pollutant Controlled
Forestry Agriculture Urban Liquid Waste Disposal	Sediments Nutrients

Description

Where vegetation is being cleared adjacent to a watercourse, a strip of riparian vegetation should be left along the streambank. The wider the strip the more effective it will be in filtering out sediment. In agricultural lands, grass buffer strips between row crop areas and watercourses have been found very effective. Not only does a vegetative strip filter out sediment carried in overland flow, it also reduces and slows down overland flow that causes rilling and gullying on streambanks. Vegetative buffer strips add to the stability of the upper zones of the bank. This is a useful practice as cultivation up to the edge of the bank leads to a weakening of the top of the bank and contributes to bank failure.

Advantages

- economical method of reducing sediment entering the streamcourse
- important to aquatic life, retains water temperatures, does not increase BOD

Disadvantages

- often leaving a strip of vegetation may lead to its demise due to sudden exposure thus this method may prove ineffective unless well planned
- small areas taken out of production

Cost Implications

Installation costs can range from $250/hectare for minimal tillage and manual broadcasting of seed to $3000/hectare for hydroseeding with mulch, however, costs due to land removed from production must also be considered.

Previous Experience

The retention of vegetative buffer strips around fence lines and adjacent to streams and wet lands occurs naturally, however, the intentional widening of these buffer strips is not difficult.

Source of Information 181, 182,38,87,107,108,110,120,126,133,180,239,237,92,106,129.

Source: *Marshall Macklin Monaghan Limited (1977)*

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Screening criteria for evaluating management options

- *Many criteria for screening candidate management measures:*

  (i) Location within critical area; (ii) Estimated load reductions; (iii) Legal & regulatory requirements; (iv) Property ownership; (v) Site access; (vi) Added benefits; (vii) Unintended impacts; (viii) Physical factors; (ix) Infrastructure; (x) Costs; (xi) Social acceptance.

Rank alternatives & develop candidate management options

- ***Work with stakeholders*** *to identify management options for more detailed evaluation;*
- ***Develop summary chart*** *& map from worksheets + ranking of alternatives for discussion with stakeholders;*
- *Summarize & weigh* ***relevant factors*** *(e.g., relative load reductions; added benefits; costs; public acceptance; ease of construction & maintenance (Table 10-5)*

Table 10-5. Example Ranking Table to Identify Candidate Management Practices

Management Practice	Pollutant Reduction Effectiveness	Cost	Added Benefits	Public Acceptance	Maintenance	Total
Gradient terraces	2	3	1	2	4	2.4
Grassed swales	3	4	3	4	4	3.2
Wet extended detention ponds	2	3	2	3	3	2.6
Model ordinances	4	3	2	4	4	3.4

Selecting Final Management Strategy

- *Chapter 10: **Initial Screening** of feasibility of management options*

- *Chapter 11: **Work with stakeholders** to:*
  (1) *Consider various strategies that use combination of management practices;*
  (2) *Rank and evaluate strategies;*
  (3) *Select preferred strategies for watershed plan.*

Selecting Final Management Strategy

- ***Five major steps:***

(1) *Identify* ***factors influencing selection*** *of management strategies;*

(2) *Evaluate* ***ability of strategy*** *to meet watershed management objectives;*

(3) ***Quantify expected load reductions*** *from management strategies;*

4) ***Identify capital and O&M costs****; compare initial and long-term costs/benefits;*

(5) ***Select*** *final preferred strategy(ies)*

Factors influencing selection of management strategies

- ***Several considerations:***

(1) *General & specific types/locations of management practices to be used;*

(2) *Indicators for evaluating performance;*

(3) *Appropriate scale & detail of analysis to assess cumulative benefits of multiple practices*

Factors influencing selection of management strategies

- ***General types of management practices:***

- *How to be applied:*

  Example: Across land area (tillage; fertilizer management) vs. along stream corridor (linear practices; riparian /stream buffer zones) vs. at specific location (treat runoff from specific drainage area via settling, infiltration, etc.)

Factors influencing selection of management strategies

- ***<u>Indicators to measure performance:</u>***

- *Defines types of analyses to assess effectiveness of management practices;*

- *Can be based on pollutant loads (easiest), hydrologic factors, concentrations, habitat, etc. measures;*

- *Ensure information is applicable to situation*

Selecting Suitable Approach to Evaluate Management Practices

- ***Evaluating performance of management practices*:**

Simple *(published literature values; spreadsheet tool) vs.* ***Complex*** *(detailed watershed model) vs.* ***Combination****;*

- *Sometimes very simple approaches are appropriate → relative comparisons of management practices (Vollenweider phosphorus loading diagrams);*

Selecting Suitable Approach to Evaluate Management Practices

- ***Approaches for evaluating performance of management practices/strategies:***

(1) ***Literature values:*** *% removal associated with each practice & pollutant (e.g., detention pond & sediment);*

- Often ranges (many factors influence performance; e.g., local climatic conditions, type of pollutant, design specifications, etc.);

Selecting Suitable Approach to Evaluate Management Practices

- ***<u>Approaches for evaluating performance of management practices/strategies</u>:***

  - Simple spreadsheets of watershed-scale reductions can be calculated → accounting of estimated loadings; areas treated; percent pollutant reductions, etc. (Fig. 11-2);

  -

Conventional till: 120 ac x 1.6 tons/ac/yr = 192 tons/yr
No-till: 120 ac x 1.6 tons/ac/yr x (1 – 0.75) = 48 tons/yr

Your net reduction is 144 tons/yr for the selected site.

If you want to evaluate this practice on a larger scale for several sites throughout the watershed, you can use a spreadsheet to facilitate the calculation. For example, suppose your watershed has 10 potential sites where conventional till could be converted to no-till. Each site has a unique area, of course, but you have also calculated loading rates for each site, based on variations in slope and soil composition:

Site	Area (ac)	Loading Rate (tons/ac/yr)	Load (tons/yr)	Removal Percentage	Load Removed (tons/yr)	Net Load (tons/yr)
1	120	1.6	192	75	144	48
2	305	1.8	549	75	412	137
3	62	1.9	118	75	88	30
4	245	1.7	417	75	312	105
5	519	1.6	830	75	623	208
6	97	2.1	204	75	153	51
7	148	1.9	281	75	211	70
8	75	1.5	113	75	84	28
9	284	2.0	568	75	426	142
10	162	1.8	292	75	219	73
Total	2,017	N/A	3,564	N/A	2,672	892

From this analysis, you estimate that altogether converting to no-till on 10 sites will remove 2,672 tons of sediment. The spreadsheet environment provides a powerful tool for testing and combining results for various scenarios. For example, you might test combinations of other management practices, with varying removal at each site.

Figure 11-2. Using a spreadsheet analysis to evaluate one management practice at a single site.

Selecting Suitable Approach to Evaluate Management Practices

- ***Approaches for evaluating performance of management practices/strategies:***

(2) ***Models:*** *Current models have significant capacities to represent management practices (EPA websites; publications; journal articles);*

- Practices they evaluate, however, vary on basis of model specialty (e.g., agricultural runoff vs. urban structural practices)

Selecting Suitable Approach to Evaluate Management Practices

- ***Approaches for evaluating performance of management practices/strategies:***

  - Chapter 8 → ***7 models***:
    Agricultural practices: SWAT, AGNPS; GWLF; STEPL;
    Urban practices: P8-UCM; STEPL; SWMM;
    Mixed Land Uses: STEPL; HSPF

    Table 11-1 → Capabilities of selected models; Each has slightly different approach to address management practices

Table 11-1. Summary of Management Practice Representation Capabilities of the Selected Models

Model	Types of Practices Considered	Strengths	Limitations
STEPL	• Contour farming • Filter strip • Reduced-tillage systems • Streambank stabilization and fencing • Terracing • Forest road practices • Forest site preparation practice • Animal feedlot practices • Various urban and low impact development (LID) practices (e.g., detention basin, infiltration practices, swale/buffer strips)	• Easy to use; good for giving quick and rough estimates • Includes most major types of management practices	• Simplified representation of management practices using long-term average removal percentage does not represent physical processes • Developed based on available literature information that might not be representative of all conditions
GWLF	• Agricultural area management practices (e.g., contouring, terracing, no-till)	• Easy to use • Long-term continuous simulation	• Does not have structural management practice simulation capabilities
HSPF	• Agricultural practices • Impoundment • Buffer	• Can simulate both area and point management practices • Provides long-term continuous simulation • Land and management practice simulation are linked	• Weak representation of structural point practices • Requires moderate to high effort to set up
SWMM	• Detention basin • Infiltration practices	• Can simulate both area and point management practices • Long-term continuous simulation • Physically based simulation of structural management practices • Management practice simulation is coupled with land simulation	• Limited representation of non-urban area practices • Requires moderate to high effort to set up
P8-UCM	• Detention basin • Infiltration practices • Swale/buffer strip • Manhole/splitter	• Tailored for simulating urban structural practices • Long-term continuous simulation • Process-based simulation for structural practices • Management practice simulation is coupled with land simulation, which provides dynamic input to drive practice simulation	• Cannot simulate nonstructural and area practices
SWAT	• Street cleaning • Tillage management • Fertilizer management • Pesticide management • Irrigation management • Grazing management • Impoundment • Filter strips	• Strong capabilities for simulating agricultural area practices • Ability to consider crop rotation • Long-term continuous simulation	• Limited urban and structural practice simulation
AnnAGNPS	• Feedlot management • Tillage management • Fertilizer management • Pesticide management • Irrigation management • Impoundment	• Strong capabilities for simulating agricultural area management practices • Long-term continuous simulation	• Limited urban and structural practice simulation

Summary of Management Practices Simulated by the Seven Models

- AGNPS—agricultural practices, tillage, nutrient application
- STEPL—removal percentages for multiple practices
- GWLF—agricultural practices, tillage, simplified nutrient/manure applications
- HSPF—urban and agricultural practices, nutrient applications, detention, and buffer areas
- SWMM—urban practices, including detention and infiltration
- P8-UCM—urban practices, including detention
- SWAT—agricultural practices, tillage, nutrient applications

Table 11-2. Summary of Management Practice Simulation Techniques of the Selected Models

Model	Management Practice Evaluation Techniques	Water Quality Constituents
AnnAGNPS	• Sediment - RUSLE factors • Runoff curve number changes • Storage routing • Particle settling	• Sediment • Nutrients • Organic carbon
STEPL	• Sediment - RUSLE factors • Runoff curve number changes • Simple percent reduction	• Sediment • Nutrients
GWLF	• Sediment - USLE factors • Runoff curve number changes • User-specified removal rate	• Sediment • Nutrients
HSPF	• HSPF infiltration and accumulation factors • HSPF erosion factors • Storage routing • Particle settling • First-order decay	• Sediment • Nutrients
SWMM	• Infiltration • Second-order decay • Particle removal scale factor • Sediment - USLE (limited)	• Sediment • User-defined pollutants
P8-UCM	• Infiltration - Green-Ampt method • Second-order decay • Particle removal scale factor	• Sediment • User-defined pollutants
SWAT	• Sediment - MUSLE parameters • Infiltration - Curve number parameters • Storage routing • Particle settling • Flow routing • Redistribution of pollutants/nutrients in soil profile related to tillage and biological activities	• Sediment • Nutrients • Pesticides

Note: MUSLE = Modified Universal Soil Loss Equation; RUSLE = Revised Universal Soil Loss Equation; USLE = Universal Soil Loss Equation.

Selecting Suitable Approach to Evaluate Management Practices

- ***<u>Approaches for evaluating performance of management practices/strategies</u>:***

  - *Model* ***information needs can vary widely (Table 11-3)***

Table 11-3. Data Needs for Management Strategy Modeling

Model	Data Needs for Management Practices
AnnAGNPS	• Tillage area, type and date, crop rotation • Fertilizer application rate, method, and dates • Manure application rate, method, and dates • Strip cropping location and area • Impoundment size and discharge rate • Sediment settling rate
STEPL	• Land use type and condition • Practice type
GWLF	• Crop type and condition • Manure application rate and date • Runoff nutrient concentration
HSPF	• Land use type and pollutant accumulation rates • Nutrient and pathogen application rates and dates • Impoundment size and discharge rates • Settling rate and pollutant decay rate
SWMM	• Land use type and pollutant accumulation rates • Impoundment size, shape, and discharge rate • Settling rates and pollutant decay rates • Street cleaning frequency and areas affected
P8-UCM	• Point practice drainage area • Impoundment size and discharge rate, pollutant decay rate • Bioretention size and infiltration rate • Street cleaning frequency and area affected
SWAT	• Tillage area, type and date, crop rotation • Fertilizer and pesticide application rate, method, and dates • Manure application rate, method, and dates • Filter strip width • Grazing dates and vegetation biomass affected • Street sweeping pollutant removal rate, date, and curb length

Selecting Suitable Approach to Evaluate Management Practices

- ***Approaches for evaluating performance of management practices/strategies:***

  - *Other Available Models (Table 11-4):* Usually more specialized

    SET; PGC-BMP; MUSIC; IDEAL; VFSMOD; REMM; WEPP; EPIC; WETLAND; VAFSWM;

Quantify expected load reductions from management practices

- *Needed load reductions* ***typically output of calculation and/or modeling exercises*** *(assuming management practice, area applied, conditions of application, etc. have been accurately represented in spreadsheet or model).*

Identify costs and benefits of management practices

- *Economics **ALWAYS** consideration in evaluating & formulating management strategies;*
- *To extent possible, cost estimates should include **<u>all</u>** future costs of management strategy (design & engineering; construction; labor; O&M; discounting).*

Table 11-5. Considerations for Applying Management Practice Unit Cost Measures

Example Management Practice	Example Cost Units	Issues to Consider Before Using Unit Costs
Grass swale	$ per linear foot	Find out the width of swale assumed in the unit cost, and make sure the width is appropriate for your project. You will overestimate the cost if you use a unit cost based on a swale that is wider than your proposed swale.
Water quality swale (dry swale)	$ per square foot	Find out whether the width should be measured across the filter media or across the entire swale. You will overestimate the cost if you measure across the entire swale, and the unit cost refers to only the filter media width.
Wet detention pond	$ per cubic foot	Determine the height at which to measure the pond volume. If the cost estimate assumes the volume up to the emergency spillway, using the volume of the permanent pool would underestimate the pond cost.
Bioretention	$ per impervious acre treated	This cost estimate format might not be appropriate for all uses. If your bioretention cell is treating a large amount of pervious area (e.g., grass lawn), this unit cost would not accurately represent the size of the bioretention cell needed.
Stormwater wetland	$ per acre of drainage area treated	This unit cost would not account for how drainage areas vary in the amount of impervious surface. Before using this type of estimate, you should make sure that it assumes a level of imperviousness similar to that of your stormwater wetland's drainage area.

Identify costs and benefits of management practices

Nonstructural management options:

-for nonstructural management options (e.g., training programs), most costs = labor;

Agriculture: *www.epa.gov/owow/nps/agmm*

Forestry:
www.epa.gov/owow/nps/forestrymgmt

Urban areas:
www.epa.gov/owow/nps/urbanmm/index.html

Identify costs and benefits of management practices

- ***Compare costs & benefits of practice:***

- *Lowest "cost-effectiveness ratio"*
  → most benefit for least dollars spent;
- *BUT still need to determine if most cost effective options meets management goals (sometimes more expensive practices necessary);*

Point: *When used in reconciling project objectives & stakeholder concerns, cost-benefit analysis can be very useful in management decision-making AND convincing stakeholders*

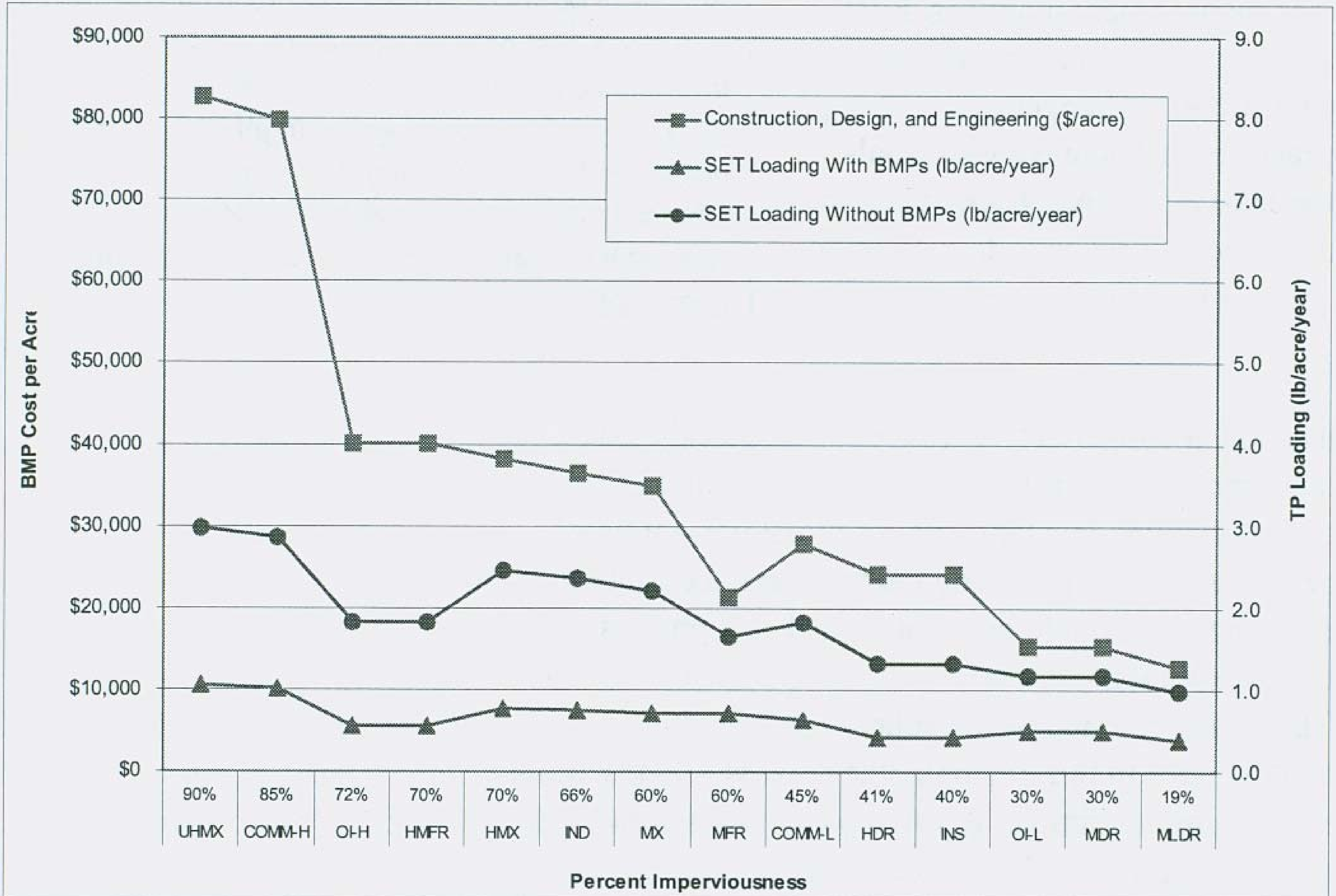


Figure 11-7. Example comparing construction cost and pollutant loading for different urban land use types with decreasing levels of imperviousness.

Select Final Management Strategies

- ***<u>Decision Process</u>:***

  (1) ***Develop Decision Criteria;***

  (2) ***Summarize Evaluation Results*** *and Present to Stakeholders;*

  (3) *Obtain* ***Stakeholder Feedback;***

  (4) ***Rank Preferences*** *and* ***Select Final Strategy(ies)***

Select Final Management Strategies

(1) <u>Develop Decision Criteria</u>:

- Need to address not only state or local water quality and/or hydrology goals, but also such issues as:

- Fiscal impacts on local government;

- Overall regulatory feasibility;

- Compatibility with other local planning objectives/policies;

- Overall political feasibility

Select Final Management Strategies

(2) <u>Summarize Evaluation Results and Present to Stakeholders</u>:

Before meeting with stakeholders, develop "big picture" summary chart (sometimes difficult);

- Both quantitative (does program meet targets?) & subjective (is program compatible with local policies; politically feasible?) indicators may be needed;

Select Final Management Strategies

(3) **_Obtain Feedback from Stakeholders:_**

- *Determine if information readily available to address any stakeholder concerns;*
- *If cost feasibility is issue, present cost-sharing information or other funding options;*
- *Always keep "end view" in mind, and focus on solutions stakeholders willing to implement*

Select Final Management Strategies

(4) ***Rank Preferences and Select Final Strategies:***

- *Can be straight forward if small watershed & limited number of landowners and/or limited number of problems to solve;*

- *Management practice worksheets (cost-effectiveness) might be adequate to highlight feasible options*

LAKE ERIE PHOSPHORUS LOAD REDUCTION ALTERNATIVES

Measure		Incremental P Reduction (mt/a)	Incremental Annual Cost ($ million/a)	Annual Incremental Unit Costs ($million/mt reduction)
URBAN POINT SOURCES:				
STP Effluent Reductions:				
(a) 1 mg/L to	USA:	1180	9.0	
0.5 mg/L	CDN:	125	1.5	
		1305	10.5	8.0
(b) 0.5 mg/L to	USA:	580	54.5	
0.3 mg/L	CDN:	65	6.5	
		645	61.0	95.5

Measure		P Reduction (mt/a)	Annual Cost ($ million/a)	Unit Costs ($million/mt reduction)
URBAN NONPOINT SOURCES:				
Level 1 (= Program of reduction at source):				
	USA:	425	34.0	
	CDN:	20	2.5	
		445	36.5	82.0
Level 2 (= Level 1 + detention/sedimentation):				
	USA:	575	89.5	
	CDN:	40	7.0	
		615	96.5	165.9

Measure	Incremental P Reduction (mt/a)	Incremental Annual Cost ($ million/a)	Annual Incremental Unit Costs ($million/mt reduction)
RURAL NONPOINT SOURCES:			
Level 1 (= Sound Management; 10% P reduction)			
USA:	350	Minimal	
CDN:	100	Minimal	
	450		Minimal
Level 2 (= Level 1 + buffer strips, strip cropping, improved drainage practices; 25% P reduction)			
USA:	200	12.5	
CDN:	150	10.0	
	350	22.5	64.3
Level 3(= Level 2 + greater intensity of effort)			
USA:	180	32.5	
CDN:	125	20.5	
	305	53.0	174.0

Summary of Minimum Cost Phosphorus Control Options to Achieve Great Lakes Target Loads

Basin	P Reduction (metric tons)	Annual Costs (US $)
LAKE ERIE		
0.5 mg/L effluent concentration[a]	1,305	$10.9 million
Level 1 rural nonpoint sources[b]	450	Minimal
Level 2 rural nonpoint sources[c]	350	$22.5 million
Level 1 urban nonpoint sources[d]	445	$36.5 million
TOTAL	2,550	$69.5 million
LAKE ONTARIO		
0.5 mg/L effluent concentration[a]	1,000	$7.5 million
Level 1 rural nonpoint sources[b]	80	Minimal
Level 1 urban nonpoint sources[d]	140	$14.0 million
TOTAL	2,420	$21.5 million
LAKE HURON		
0.5 mg/L effluent concentration[a]	410	$2.5 million
Level 1 rural nonpoint sources[b]	90	Minimal
Level 2 rural nonpoint sources[c]	75	$4.0 million
Level 1 urban nonpoint sources[d]	105	$8.0 million
TOTAL	680	$14.5 million
OVERALL TOTAL	5,650	$105.5 million

[a]Reduction from 1 mg/L to 0.5 mg/L for STPs>1 MGD.
[b]Level 1 rural sound NPS practices applied to all agricultural lands.
[c]Level 2 rural NPS applied to all croplands/areas of fine-textured soils.
[d]Level 1 urban NPS measures applied to all urban lands.

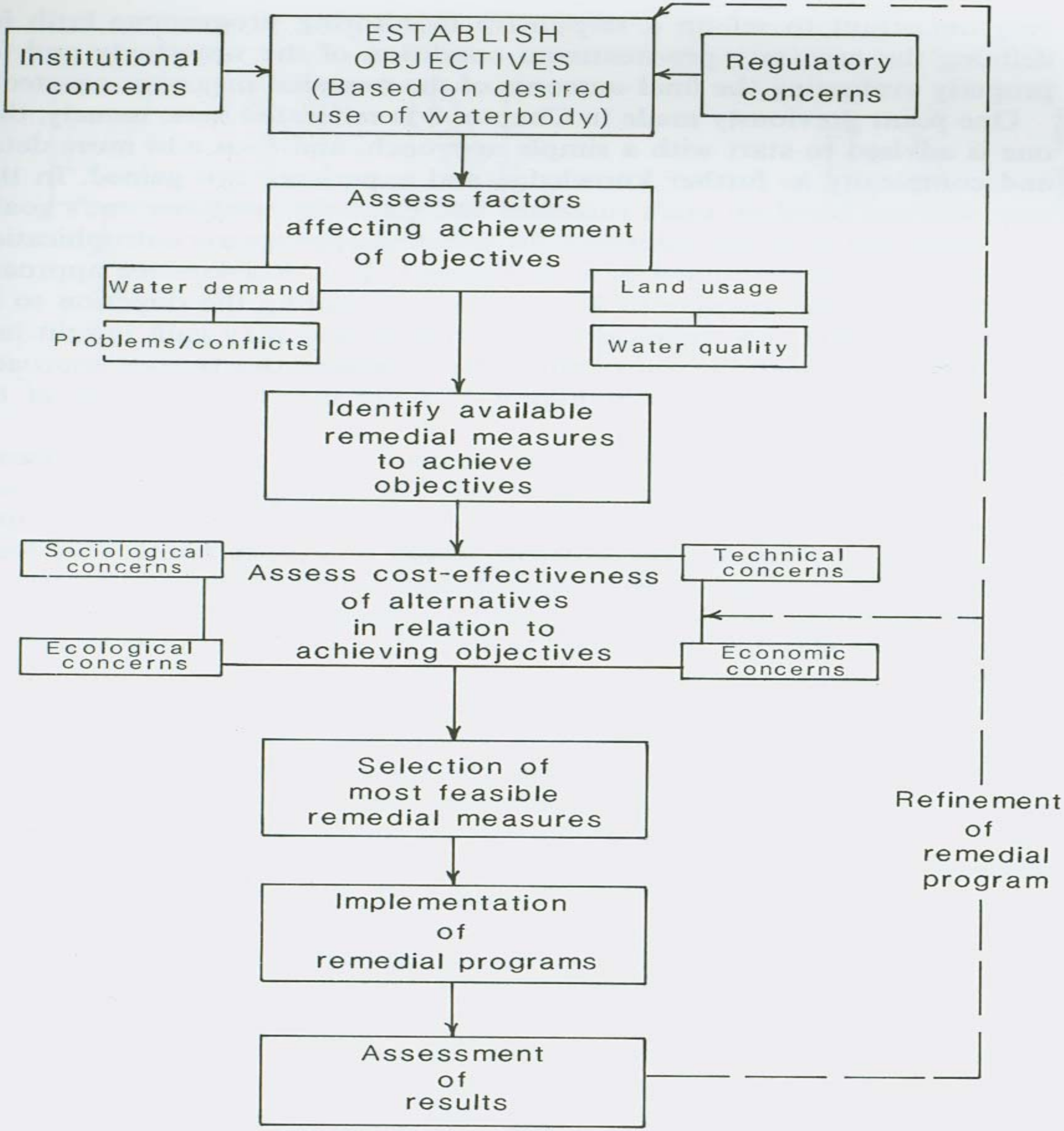
Select Final Management Strategies

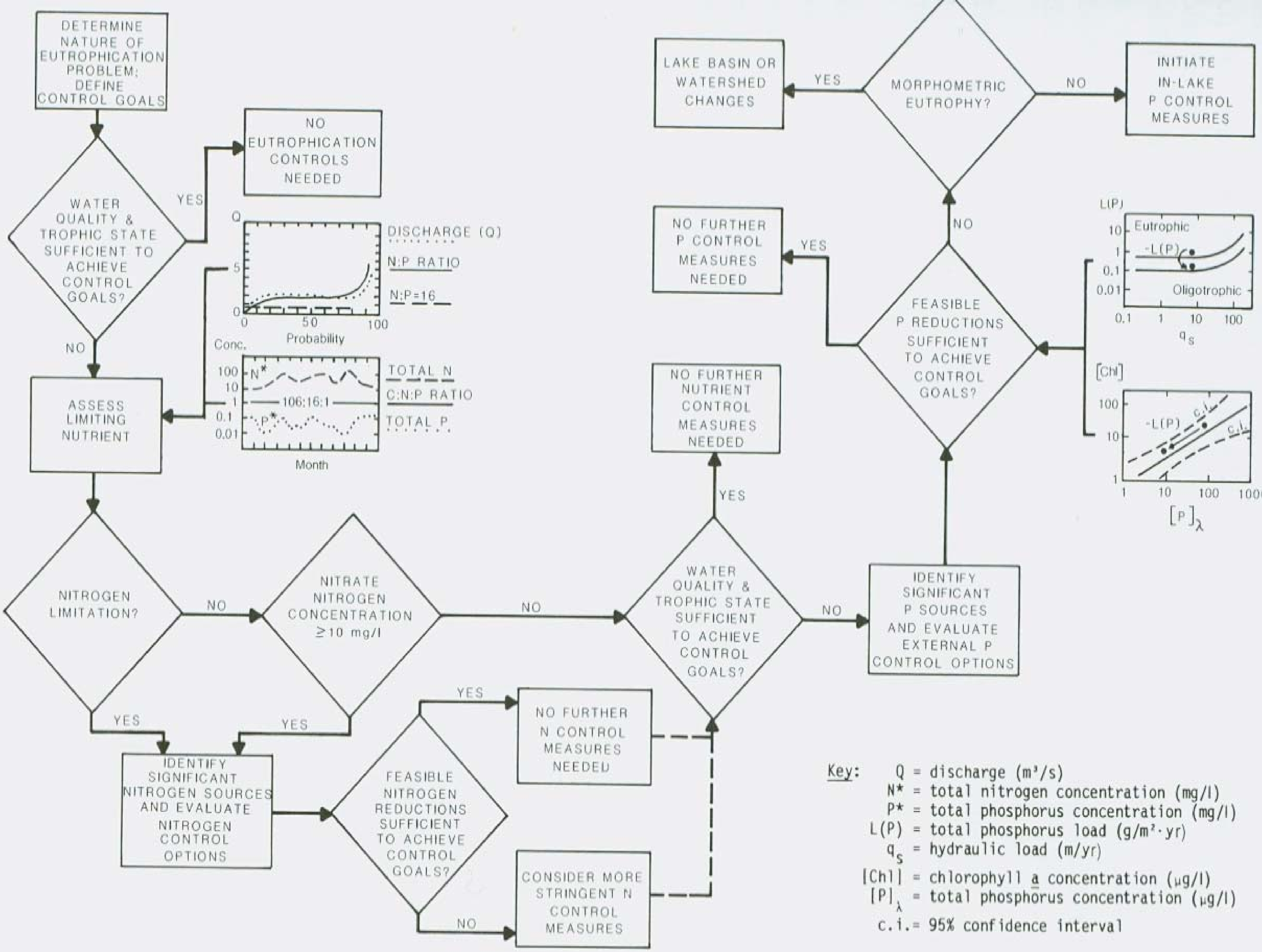
(4) ***Rank Preferences and Select Final Strategies:***

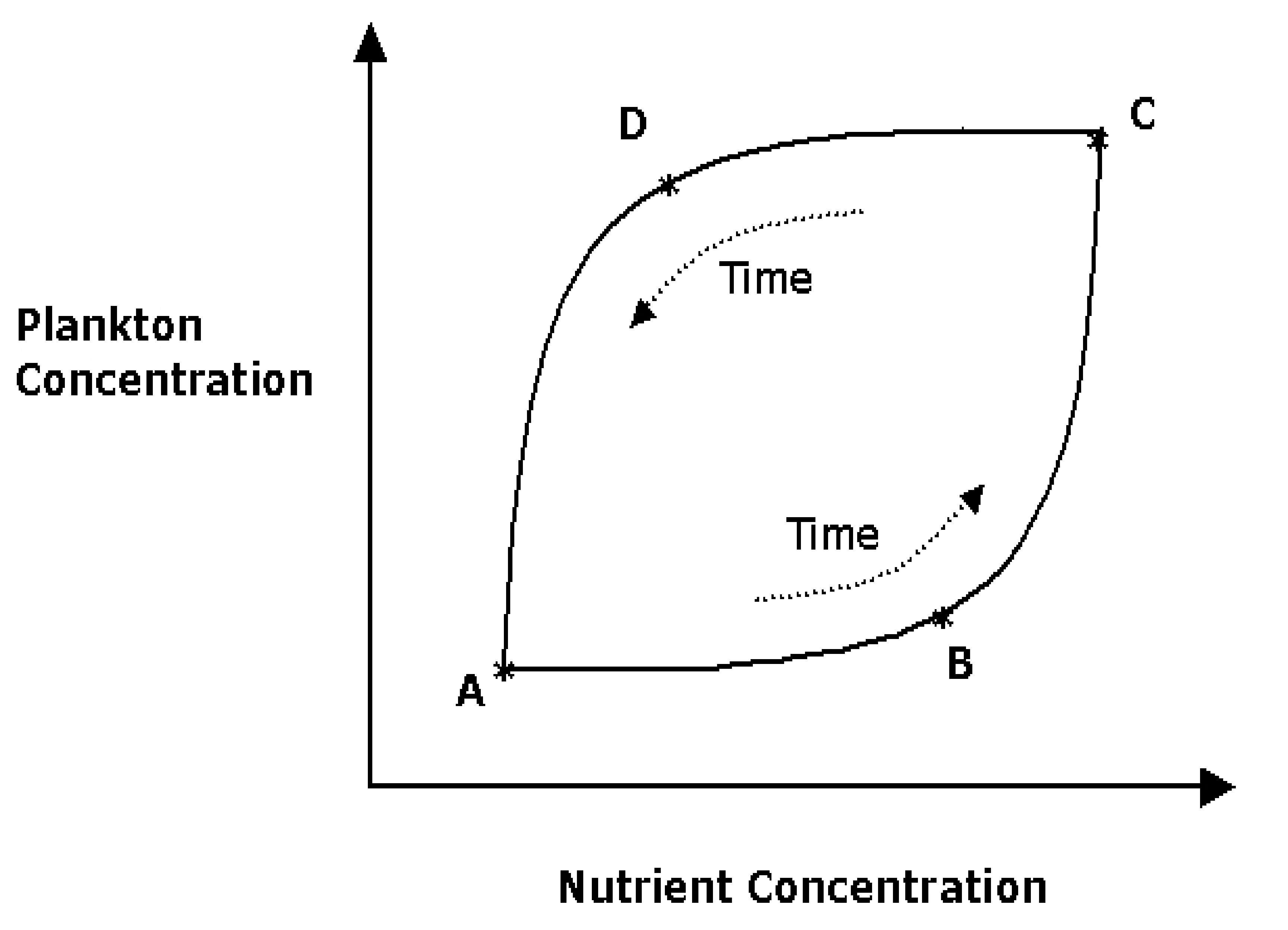
- More complex with larger watersheds or small watershed with multiple problems & broader set of stakeholders;

- May be necessary to develop formal criteria and methods for ranking stakeholder preferences;

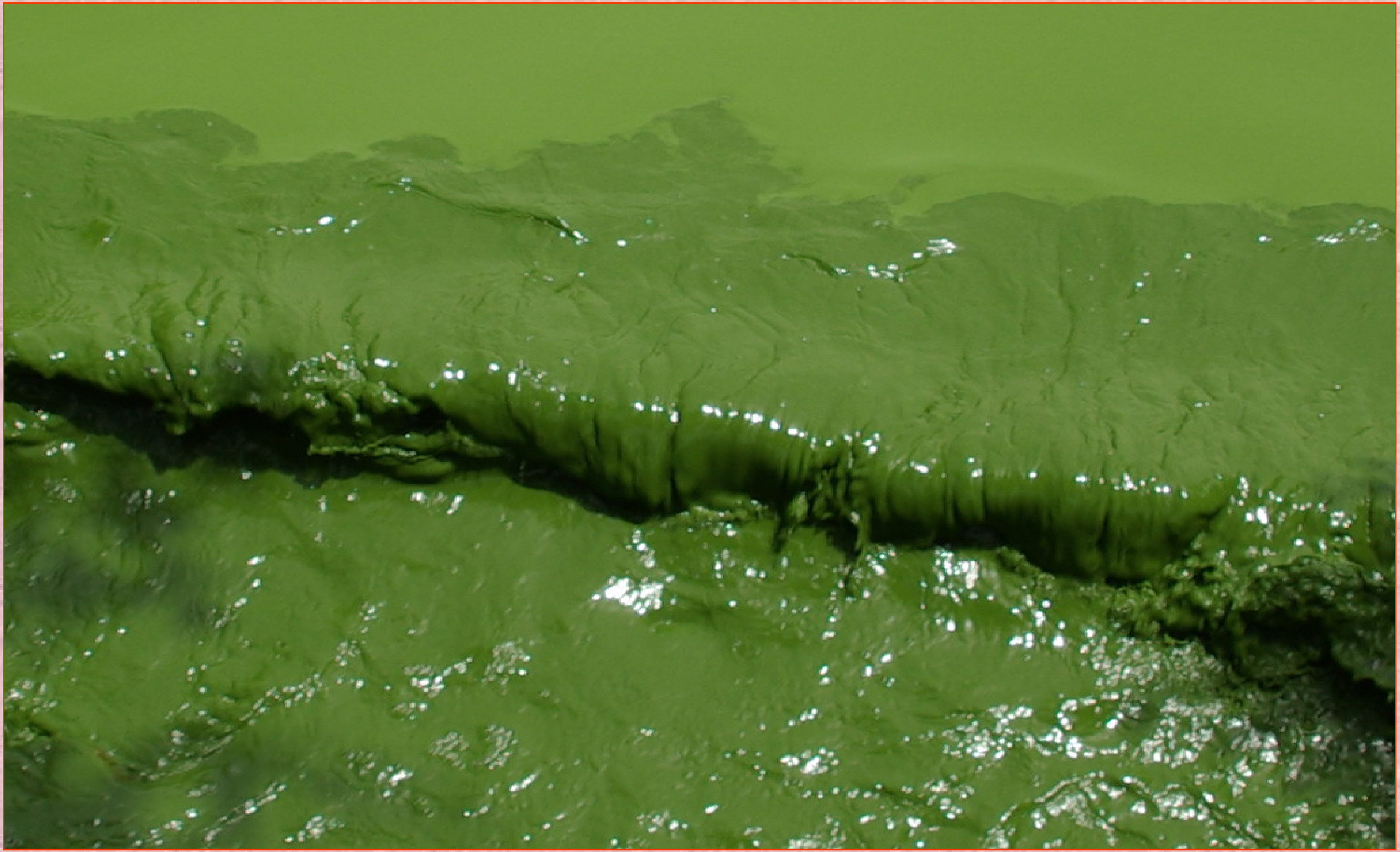
Remember: *Many ways to rank and select desired management strategy*


Institutional concerns
ESTABLISH OBJECTIVES (Based on desired use of waterbody)
Regulatory concerns
Assess factors affecting achievement of objectives
Water demand
Problems/conflicts
Land usage
Water quality
Identify available remedial measures to achieve objectives
Sociological concerns
Ecological concerns
Assess cost-effectiveness of alternatives in relation to achieving objectives
Technical concerns
Economic concerns
Selection of most feasible remedial measures
Implementation of remedial programs
Assessment of results
Refinement of remedial program


DETERMINE NATURE OF EUTROPHICATION PROBLEM; DEFINE CONTROL GOALS
WATER QUALITY & TROPHIC STATE SUFFICIENT TO ACHIEVE CONTROL GOALS?
YES
NO
NO EUTROPHICATION CONTROLS NEEDED
Q
DISCHARGE (Q)
N:P RATIO
N:P=16
Probability
Conc.
N*
P*
106:16:1
TOTAL N
C:N:P RATIO
TOTAL P
Month
ASSESS LIMITING NUTRIENT
NITROGEN LIMITATION?
NITRATE NITROGEN CONCENTRATION ≥10 mg/l
IDENTIFY SIGNIFICANT NITROGEN SOURCES AND EVALUATE NITROGEN CONTROL OPTIONS
FEASIBLE NITROGEN REDUCTIONS SUFFICIENT TO ACHIEVE CONTROL GOALS?
NO FURTHER N CONTROL MEASURES NEEDED
CONSIDER MORE STRINGENT N CONTROL MEASURES
WATER QUALITY & TROPHIC STATE SUFFICIENT TO ACHIEVE CONTROL GOALS?
NO FURTHER NUTRIENT CONTROL MEASURES NEEDED
IDENTIFY SIGNIFICANT P SOURCES AND EVALUATE EXTERNAL P CONTROL OPTIONS
FEASIBLE P REDUCTIONS SUFFICIENT TO ACHIEVE CONTROL GOALS?
NO FURTHER P CONTROL MEASURES NEEDED
MORPHOMETRIC EUTROPHY?
LAKE BASIN OR WATERSHED CHANGES
INITIATE IN-LAKE P CONTROL MEASURES
L(P)
Eutrophic
Oligotrophic
q_s
[Chl]
c.i.
$[P]_\lambda$
Key: Q = discharge (m³/s)
N* = total nitrogen concentration (mg/l)
P* = total phosphorus concentration (mg/l)
L(P) = total phosphorus load (g/m²·yr)
q_s = hydraulic load (m/yr)
[Chl] = chlorophyll a concentration (µg/l)
$[P]_\lambda$ = total phosphorus concentration (µg/l)
c.i. = 95% confidence interval


Plankton
Concentration
D
C
Time
Time
B
A
Nutrient Concentration

“water-blooms” in Lake Taihu, China”



"A vision without action
is just a dream;
An action without vision
just passes time;

A vision with an action
changes the world."

……..World Lake Vision (2003)

General Approach for Meeting Pollution Objectives

(1) ***Identify pollution problem and establish management goals:***

- *What is nature of pollution & why a problem?*
- *How can control goals be determined?*
- *Who should be involved in managing problem?*

(2) ***Assess information available about waterbody:***

- *What information is necessary?*
- *How can it be obtained?*

General Approach for Meeting Pollution Objectives

(3) **Identify Available Options for Managing Pollution:**

- Manage cause or symptoms?
- What options are available?

(4) **Analyze All Costs & Expected Benefits of Available Options:**

- What are the estimated costs?
- What resources are available?
- What are costs & benefits of available options?
- What if nothing is done about problem?

General Approach for Meeting Pollution Objectives

(5) Analyze adequacy of legislative & regulatory framework for implementing pollution control program:

- Are existing institutions & regulations adequate?
- If new ones are needed, how to develop them?

(6) Select Pollution Control Program; Distribute Summary to Affected Parties Prior to Implementation

- How can appropriate pollution program be selected?
- What information should be distributed; to whom?
- Should public education program be part of Program?
- Any other important considerations?

General Approach for Meeting Pollution Objectives

(7) Provide Periodic Progress Reports to Public & Other Interested Stakeholders:

- How can public be made better aware of pollution control program?

- What is the importance of public feedback and how best used?